"ANALYSIS OF DORSAL KNUCKLE CREASE PATTERNS FOR PERSONAL IDENTIFICATION"

A Synopsis

Submitted to

Shri Vaishnav Vidyapeeth Vishwavidyalaya

For the Partial Fulfilment of the Degree of

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in

Forensic Science

Submitted by:

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INTRODUCTION
In spite of various available methods for identification and individualization like dactyloscopy, anthropometry, iris prints, ear prints, lip prints etc., identification is still a challenging task in forensic investigation. Identification is not only restricted to forensic examination but it has wide applications in civil practices too e.g., Security check-ins, banking, smart cards, various types of licences, personal IDs etc. In the present time though, various biometric traits have been studied and are in use, fingerprints are still considered one of the best biometric or identification traits. A lot of studies have been done on the palmer surface of the hand like fingerprints, ridge density, palm prints, vein patterns etc. but very limited studies are available on the dorsal surface of the hand for identification purposes. Like fingerprints, the dorsal surface of the hands also consists of minutiae and skin crease patterns which are considered to be permanent in nature throughout life (Charles, 1997). These patterns are known as Finger Knuckle Prints or Knuckle Crease patterns.
Anatomy of Finger A human hand comprises five digits: thumb, index finger, middle finger, ring finger and little finger. Each finger comprises of 3 phalanges referred to as proximal phalange, middle phalange and distal phalange. While the thumb has only 2 phalanges i.e., proximal and distal phalange. In all, a hand consists of 14 phalanges. Phalanges are bones that make up the finger while phalanx is its singular which refers to a single finger bone. All three phalanges of the finger are depicted in Figure 1.
• Proximal phalanx: It is the longest of the three finger bones and is closest to the palm. • Middle phalanx: It is the bone in between the proximal and distal phalanx. • Distal phalanx: It is the smallest of the three finger bones and is farthest from the hand.

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Anatomy of Finger

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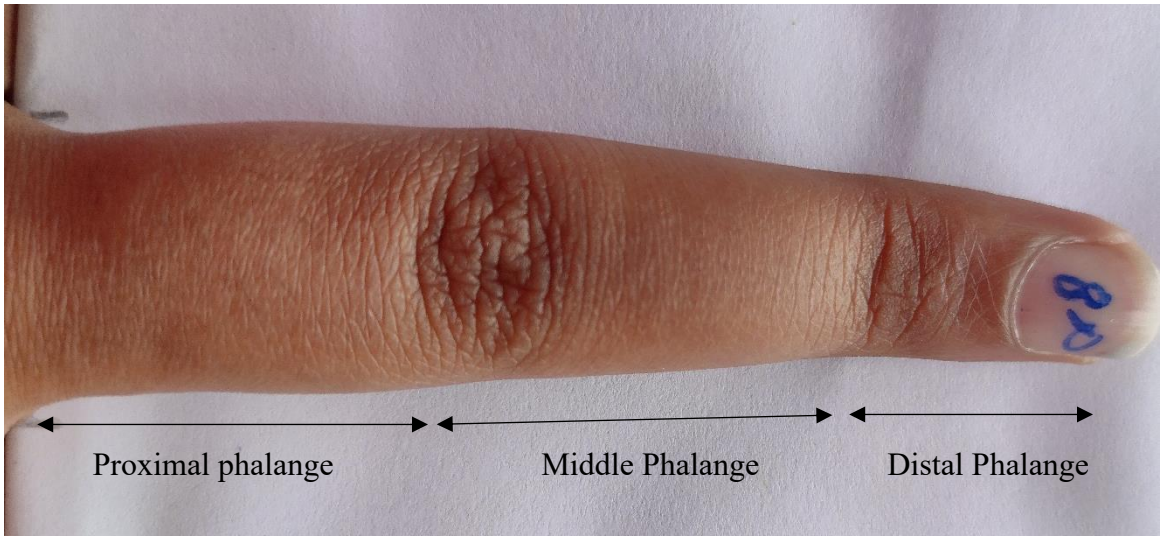

Figure 1. Phalanges of Finger

Finger Joints

Finger joints are referred to as knuckles. Each finger has three joints, while the thumb has only 2.

- **Metacarpophalangeal joint (MCP):** It is the largest joint of the finger which lies in between the fingers and hand. The metacarpal bone of the fingers and thumb connects to the proximal phalanx.
- **Proximal interphalangeal joint (PIP):** It is the middle joint of a finger. It connects the proximal and middle phalanx. This joint is not present in the thumb.
- **Interphalangeal joint (IP):** Only the thumb has this joint. It connects distal and proximal phalanges.
- **Distal interphalangeal joint (DIP):** It is the joint of a finger which is closest to the fingertip. It connects the middle and distal phalanges. This joint is not present in the thumb.

Crease patterns present on these knuckle joints are considered to be permanent in nature. Distribution of collagen fibres in the fingers determines the tension lines and wrinkle lines in the finger. (Warwick & William, 1973). When the fingers are flexed, they tend to run parallel to the crease that appears (Moore & Dalley, 2005).

Advantages of using Finger Knuckle Crease Pattern (FKCP)

- **Quality of prints in case of farmers or hard workers:** Fingerprints of labourers, farmers and hard workers are very much damaged because of rough hand usage, which causes severe damage to their fingerprints which are often permanent in nature. So, fingerprints cannot be used in their case as a biometric trait for identification. But knuckle crease patterns remain unaltered as the dorsal surface of the hand is not used much.
- **Threat of theft or misuse:** Fingerprints can easily be left on any surface and can easily be picked up and misused as the palmer surface of the hand comes in contact very often but in the case of Finger knuckle crease patterns, this is not true as the dorsal surface of hands is used less often.
- **Contactless capture:** A Camera is used to capture the Finger knuckle crease patterns which allows for non-invasive contactless imaging thus it ensures personal hygiene and convenience.
- **Child Pornography cases:** In such cases, if close-up video shots of hand are available, the identity of the perpetrator of child pornography can be established.

  This method can also be used to identify the victim if the face of the victim is blurred or not visible. In Dean Hardy's 2012 case, finger knuckle images were used as forensic evidence. Forensic anthropologists identified distinctive finger knuckle

(freckles) on the hand of the culprit (seen in the images), which were similar to that of Hardy (Kumar, 2014).

- **Supportive tool:** It can be used as a supportive tool to identify the suspect or victim.
- **Not easy to abrase and pilfer:** Unlike fingerprints, knuckle crease patterns cannot be abraded or pilfer easily.

According to ISO/IEC 2382-37:2022 standard, any potential 'biometric characteristic' should be able to ensure 'repeatable biometric features' to be able to serve as useful biometrics (ISO, 2022) and it is very important in the field of forensics too as in forensic cases the time interval between the crime conducted and capturing the culprit could be of years. As finger knuckle crease patterns have recently emerged as biometric traits there are not many person-specific studies over a large time interval. In this context, Kumar, 2014 has proved in his study that knuckle creases and lines are stable by studying the images of knuckle patterns acquired over a time-lapse of 4 to 7 years on the subjects of various age groups.

Epidermal ridges on the knuckle creases are unlikely to change throughout the life of an individual in nature (Charles, 1997). Chattopadhyay & Sukul (2012) stated that "Skin creases on the dorsal aspect of the proximal interphalangeal joints are identical in texture and composition to the knuckle skin and hence can be assumed to remain unchanged throughout life". With the progression in age, the skin becomes loose still the creases persist without any alteration. This forms the basis of the present study.

REVIEW OF LITERATURE

A lot of work has been already done on fingerprints and palm prints, but Finger knuckle crease patterns are been emerging as a new biometric trait for personal identification and there is a broad scope of research studies in this field. Very few studies related to knuckle crease patterns have been reported till now. Important studies done in the field of knuckle crease patterns are summarized as follows:

Woodard and Flynn (2005) were the first to propose that Finger knuckle crease patterns are unique patterns which can be used as a biometric tool for personal identification. They collected the data with a 3-D sensor Minolta 900/910. They used a linear regression method and normalization coefficient for feature template generation and matching shape index values. They achieved an EER of 5.5%.

Black et al. (2009) in their research paper have described the case of Dean Hardy in which he was pleaded guilty based on image comparison evidence of his hand which includes matching of knuckle freckles on his thumb. Dean Hardy was arrested in 2007, and lots of porn images of children were found on his computer. Out of numerous images found, five images consist of the offender's hand in it. Those images were matched with Hardy's hand and a positive result was obtained, based on which he was proven guilty in court. It was the first case in the UK in which the suspect was proven guilty based on a knuckle freckles image comparison.

Carrell (2009) has described a case of Operation Algebra (UK), in her article. The suspect was proven guilty by comparison of his hand images. 7000 indecent images of children were obtained from the computer of Niel Strachan, one of the culprits in this case. One image among this contained an image of an adult hand. By the expert examination of this hand image with that of Strachan's hand especially the thumb, the expert came to the

conclusion that both the images were of the same person. Considering this expert testimony as evidence Neil Strachan was pleaded guilty and received a life sentence at the High Court in Edinburgh, UK.

Kumar and Ravikanth (2009) proposed a new method for finger knuckle patterns identification by using textured patterns produced by bending finger knuckles. Sub-space methods were used by them for feature extraction. Their experimental results illustrate that the combination of PCA, LDA and ICA achieves the best performance with an EER of 1.39% and a DI (Decidability index) of 2.35%.

Kumar and Zhou (2009) proposed a method which incorporates Knuckle codes. Knuckle codes were generated from enhanced images of finger knuckle patterns by using Localized Radon Transform. Knuckle codes were compared by the minimum matching distance that results from the variation resulting from the translation and positioning of the fingers. Rank one recognition rate of 98.6% and EER of 1.14% was achieved.

Nanni and Lumini (2009) proposed a multi-matcher system which employs Radon transform and Haar wavelet for feature extraction from Finger knuckle prints (FKP), which were transformed by the non-linear Fisher transform and then parzen window classifier was used for matching features. They achieved an EER of 0.3%.

Zhang et. al. (2009) devised an FKP capturing device and also proposed an algorithm to process the acquired data. They proposed Band Limited Phase Only Correlation (BLDOC) method by which images can be registered and evaluated simultaneously. The FKP verification system achieved a genuine acceptance rate (97%), low false acceptance rate (0.02%) and EER (1.09%).

Badrinath et. al. (2011) used SIFT (Scale Invariant Feature Transform) and SURF (Speeded Up Robust Feature) matching scores for FKP recognition. Questioned images

were matched by the images from the dataset by using the nearest neighbour ratio method and the obtained SIFT and SURF scores were fused together by using the weighted sum rule. The proposed system was evaluated using the PolyU finger knuckle print database for both identification and verification modes. It was observed that the system performs with an EER of 0.215%.

Baines (2011) studied the knuckle crease patterns of the left index fingers of 158 individuals and attempted to classify their knuckle crease patterns at a preliminary level. Initially, he proposed 11 patterns but when additional observers checked it only 3 patterns achieved a high level of consistency. He concluded that it was not possible to classify all individuals within a cohort. He had also given a method of tracing and interpreting creases. As the sample size was less and only the index finger was used, he was not able to propose a systematic classification of knuckle crease patterns.

Chattopadhyay and Sukul (2012) studied the knuckle patterns of 257 native Bengali subjects (140 males and 117 females) from Kolkata. The digital camera was used to capture the dorsal finger knuckle patterns. The images obtained were analysed using Microsoft Photo Editor. Characteristics of the ridge were classified as five basic types of stems, i.e., horizontal, vertical, oblique, semilunar and mixed. It was observed that the horizontal stem was the most common and semi lunar stem was the least common among the samples collected. 91.9% accuracy for identification by knuckle patterns was claimed in this study. It was the first study in which the classification of finger knuckle patterns was done. Just classification of the images was done based on observation. Features like the distance between the stems, width between the stems etc. were not considered in this study.

Swati and Ravishankar (2013) presented Finger Knuckle Print recognition using Gabor filter feature extraction and KDCA (Kernel Principal Component Analysis) algorithm and LDA (Linear Discriminant Analysis) algorithm. A recognition rate of (91.67%) was achieved by this method.

Kumar (2014) conducted a study in which samples of knuckle patterns were acquired after an interval of 4 - 7 years from the subjects of the age group 4 to 59 years. Feature extraction and matching approach were used to match the images acquired after a very long interval of 4 to 7 years. In this study, minor knuckle patterns were studied. Promising results were obtained with a high verification accuracy (EER 3.62%). He concluded that there is a high degree of stability in the curved creases and lines of knuckle patterns.

Vidhyapriya & Rose (2019) proposed a method for secure biometric authentication using FKP. By using Gabor with exception maximization algorithm texture patterns were extracted and the performance was compared with the genuine acceptance rate and false rejection rate. The overall performance of the proposed approach was 98%.

Trabelsi et. al. (2020) proposed a multimodal biometric identification system by using the technique of CNN (Convolutional Neural Id identification. They concluded by their study that the use of combination finger image modalities gives the best result as compared to one finger modality. The EER of 0.000% for open-set identification was achieved.

Kadane (2020) has described the case of Devin Whitfield, who was charged with child pornography. Part of the evidence consisted of an image taken on a cell phone that included the dorsal side of the knuckles. A qualified fingerprint analyst by her experience testified, “The print of the unknown on the cell phone is the same finger and same knuckle

as Devin Whitfield. But she couldn't justify her statement in court. As a result, at the subsequent hearing, the prosecution announced that it was abandoning claims of identification. The case proceeded on other grounds and later Devin Whitefield was proven guilty.

John (2021) has performed a comparative study on finger knuckle prints on 30 subjects (15 male and 15 female) to predict sexual dimorphism in the case of finger knuckle prints and to know the uniqueness of the prints. He measured the spacing between the ridges and came to the conclusion that males tend to have more spacing in between ridges as compared to females and each and every knuckle print is unique in nature. Only three features; spacing between the ridges, ridge ending and bifurcation are studied in this study. The sample size is also very small. Only index fingers were considered for the study. No classification was done in this study.

Dan et al. (2023) studied the impact of finger flexion at knuckle crease patterns on digital images when comparing two hands at different points of flexion. Baines's method of tracing and coding was used. They reported that the comparison of knuckle creases of fingers held at 20º of hyperflexion vs 0º ($p = .10$) and 20º of hyperflexion vs 45º ($p = .09$) result in knuckle crease feature frequencies which are not significantly different when comparing knuckle crease regions from the same individual. This suggests that any significant variation in the knuckle crease feature frequencies between a suspect's and perpetrator's fingers flexed at these flexion pair combinations would not be caused by finger flexion, but have a different origin.

RATIONALE

The majority of the work done in Knuckle crease patterns is by researchers with expertise in the field of computers and biometrics, rather than anatomy or forensics. They have used software-based methods for developing knuckle crease patterns as a biometric trait. Their clear motive is to make a commercial product for identification and verification purposes. So, there is a need to develop a technique which is based on anatomical features for identifying these features, so that knuckle crease patterns can also be used as a potential identification tool in the field of forensics. There is no accurate and systematic classification of knuckle crease patterns. Hence the present study is selected and proposed to develop a systematic classification of knuckle crease patterns and to develop a technique for estimation of sex from knuckle creases so that knuckle creases can be used as an identification trait by the investigation agencies.

OBJECTIVES OF THE STUDY

The objectives of the present study are:

- To develop a systematic classification for Knuckle crease patterns using established and novel parameters.
- To ascertain sex by studying the features and dimensions of Knuckle crease patterns.
- To give Forensic significance of Knuckle crease patterns.

PROPOSED METHODOLOGY

Ethical Clearance:

Ethical clearance if required would be obtained from the university research ethics committee. Informed/written consent of the participants of the study, would be taken after explaining to them the purpose of the study and their rights according to the Helsinki Declaration.

Exclusion and Inclusion Criteria:

Healthy consenting individuals between the age group 18 to 60 will be included in the study. Individuals having any kind of skin disease, fracture of the hand or fingers, amputation, deformity, scars, any injury over the knuckle region of the finger or history of any surgery involving fingers would be excluded from the study.

Sample and Sample Size:

Stratified random sampling method would be used for this study. Samples from all 10 fingers of 400 individuals (200 males and 200 females) would be collected. i.e., the total sample size would be 4000. Demographic and other relevant details of the individual would be also taken along with the consent.

For obtaining the samples, Subjects will be asked to wash their hands with soap and water and then pat dry with a clean towel. The samples will be collected by photographing the dorsal knuckle creases against a white background with a scale marked on it. Markings would be done on the fingernails of the subject with a temporary marker pen, indicating a unique code assigned to each finger and individual. The subjects will be asked to place their fingers, without any strain, in a resting position, one by one starting from right thumb to left little finger in order, over a flat surface already marked with a scale. The dorsal

aspect of the finger will be then photographed by using a camera. The height of the camera will be fixed for taking all the photographs. Two sets of photographs will be taken for each finger and both the hands of each individual i.e., a total of 9600 photographs will be taken.

Method of Analysis:

Photographs captured by the camera will be transferred to the computer. The images will be then normalized and converted to greyscale. Software and computer-aided tools such as Microsoft Office tools, Image J software, and Adobe Photoshop tools may be used in normalising and rescaling the images. Printouts of the images will be obtained and then will be subject to further analysis using established and novel parameters. Method used by Chattopadhyay & Sukul (2012) for STEM classification would be used as a reference for classifying knuckle crease patterns, along with it some novel parameters would be also used for the classification. The proximal interphalangeal joint of the fingers and the interphalangeal joint of the thumb will be subjected to morphological and comparative analysis. Various class and individual characteristics of knuckle creases will be identified and studied manually/digitally using appropriate instruments like a handheld lens, Digital Vernier calliper, computer–aided methods etc. Qualitative and quantitative analysis of the acquired samples will be done and various statistical tests will be performed on the data acquired.

EXPECTED OUTCOMES

The expected outcomes of the present study are (but not limited to):

- It may be possible to give a systematic classification of Knuckle crease patterns.
- It may be possible to identify the sex of an individual by knuckle crease patterns.
- Forensic significance of the Knuckle crease patterns would be given.

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CHAPTER OUTLINE

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